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Linking demand and supply factors in identifying cultural ecosystem services of urban green infrastructures: a review of European studies[1]

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Abstract
Urban green infrastructure provides a number of cultural ecosystem services that are greatly appreciated by the public. In order to benefit from these services, actual contact with the respective ecosystem is often required. Furthermore, the type of services offered depend on the physical characteristics of the ecosystem. We conducted a review of publications dealing with demand or social factors such as user needs, preferences and values as well as spatially explicit supply or physical factors such as amount of green space, (bio)diversity, recreational infrastructure, etc. and linking demand and supply factors together. The aim was to provide an overview of this highly interdisciplinary research, to describe how these linkages are being made and to identify which factors significantly influence dependent variables such as levels of use, activities or health and well-being benefits. Commonly used methods were the combination of questionnaires with either on-site visual recording of elements or GIS data. Links between social and physical data were usually established either by using statistical tools or by overlaying different thematic maps. Compared to the large number of variables assessed in most studies, the significant effects in the end were relatively few, not consistent across the studies and largely dependent on the context they were seen in. Studies focused on aesthetic and recreational services, while spiritual, educational and inspirational services were not considered when creating links to spatially explicit ecological structures. We conclude that an improvement and harmonization of methodologies, cross-country studies and an expansion of this line of research to a wider range of services and more user groups could help clarify relationships and thereby increase applicability for urban management and planning.

Keywords: urban green space; urban forestry; linkage of social and physical data; spatially explicit; factors influencing well-being benefits

Introduction

Over the last 30 and especially over the last 10-15 years, urban green space has become an important research topic (Kabisch et al. 2015). With increasing urban

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populations, concerns about quality of life and human health and wellbeing have increased. With this, the interest in the potential and actual benefits of urban green spaces of all kinds – now widely referred to as urban green infrastructure – has grown (Benedict and McMahon 2006). The Millenium Ecosystem Assessment defines four types of ecosystem services (ES): provisioning, regulating, supporting, and cultural (MEA 2005). In this paper we focus on cultural ecosystem services (CES) associated with different types of public urban green space, including recreational, aesthetic, and spiritual experiences (Daniel et al. 2012). According to Daniel et al. (2012), these types are recognized but not yet adequately defined or integrated into the ES framework, being characterised as "intangible", "subjective" and "difficult to quantify". Despite this, Milcu et al. (2013) argue that capitalizing on the societal relevance of CES helps to address real-world problems. For example, they might serve as a useful gateway for addressing and managing nature in cities (Andersson et al. 2015). CES differ to some extent from other categories of ES because they normally require actual contact with the ecosystem by the individual for the benefits to materialize; the service has to be consumed or experienced on site. According to Haines-Young and Potschin (2013), they are - amongst other ES - mostly *final* ecosystem services which influence human well-being directly. This type has a strong link to the ecosystem function, process and/or structure that produces them and also suggests that attention should be paid to the location of both the supply of and the demand for these services. The widely used Cascade model (de Groot et al. 2010) reflects the origin of the ES concept in the natural sciences, suggesting a natural supply of benefits to humans from the ecosystem while paying relatively little attention to the demand for ES (see also Spangenberg et al. (2014)). Therefore we propose a somewhat different model, the Confluence model (see Fig. 1) that is described as follows.

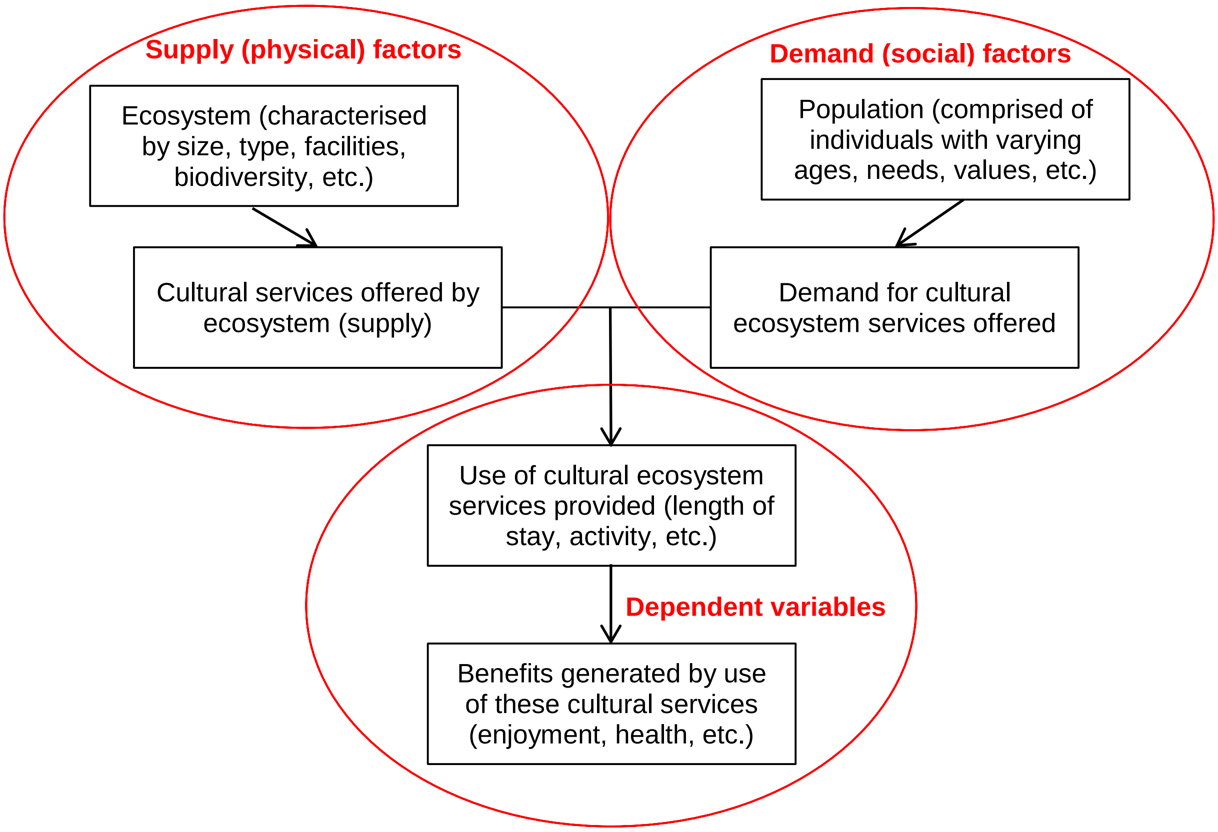

Fig. 1. The Confluence model showing how supply and demand factors determine the use of cultural ecosystem services.

Clearly, not all urban green areas offer the same types, qualities and quantities of CES - factors such as green space size and physical composition, its design and layout, as well as any facilities form the basis for their supply. Not everyone has the same demands concerning urban green spaces (Schmithüsen and Wild-Eck 2000, Arnberger 2006). The characteristics determining demand for CES will be referred to as social or demand factors. They are the socio-demographic and socio-economic characteristics of the population, as well as their general preferences and value orientations (Plieninger et al. 2013). These factors determine the match between the supply offered and the services demanded. Actual use results from a spatial match between demand and supply. Knowledge about the combination of these factors helps in predicting the extent and range of possible benefits from different configurations of green infrastructure planned, designed and managed at a city or site scale. The model can be seen as a further development of the outdoor recreation decision process by Pigram 1983 (Pigram and Jenkins 1999) in which characteristics of individuals and households form the demand and perception of resource characteristics and accessibility form the supply for outdoor recreation, resulting in decisions for the participation in outdoor recreation. The confluence model expresses these relationships in the context of ecosystem services and explicitly includes the benefits generated by the use of CES. Please note that the term "confluence model" has nothing to do with the confluence model explaining birth-order differences in intellectual performance (Zajonic and Sulloway 2007), nor with the confluence model of sexual aggression by Malamuth et al. (2008).

According to the confluence model we can group research in this field into three categories:

- Studies mainly examining demand factors, e.g. preferences for green spaces, urban forests and parks or surveys of recreational use and activities, but paying little attention to green space physical aspects or only dealing with them in spatially non-explicit ways, e.g. using photos of landscape types. Examples include Arnberger and Eder (2015), Carvalho-Ribeiro and Lovett (2011), Conedera et al. (2015) or Eriksson et al. (2012).
- Studies primarily concerned with supply factors, e.g. physical or ecological characteristics of urban forests, but paying no attention to social aspects or only including them in minor ways, e.g. national forest inventories or interviews with foresters or policy makers about recreational aspects (Tomppo et al. 2010).
- Studies which establish links between demand factors such as user preferences, etc. and supply factors, such as the physical characteristics of specific locations (Burkhard et al. 2012, Plieninger et al. 2013).

While previous reviews have looked at associations between green space and human measures (Jorgensen and Gobster 2010), we go further and quantify a) how these linkages are made and b) which factors are identified as significantly influencing (levels of) use and health and wellbeing benefits. We link social factors (the demand side) to spatially explicit physical factors (the supply side) in urban green infrastructure. Benefits arise as a match between suitable physical space (supply) and users' preferences, socio-demographic background etc. (demand). This category of studies is most relevant because spatially explicit information concerning human-environment interactions may increase its applicability in urban planning (Kabisch et al. 2015), while Beeco and Brown (2013) state that understanding the spatial context of both ecological and social data is needed to maintain visitor experience quality and to protect resources. This is challenging, because social data are rarely location-specific and difficult to integrate into spatial planning models. Hernández-Morcillo et al. (2013) found that spatially explicit measures helped to improve the quality of CES indicators. However, in their review of 42 studies, they found only 23% using spatially explicit information.

Based on the Confluence Model (Fig. 1) the research questions for our study were:

1. Which demand and supply factors are mainly combined and which have received little attention and could be the subject of future research?
2. How are demand and supply factors linked to each other? Are there (missing) linkages that could be the subject of future research?
3. Which demand and supply factors significantly influence which uses and benefits?

Methods

This study was carried out within the EU COST Action FP1204 'GreenInUrbs' with a focus on European studies, given that the concepts of urban forestry and green infrastructure emerged a lot later in Europe than in North America, are defined somewhat differently and are embedded in different historical and cultural contexts (Konijnendijk et al. 2006). We focused on studies which had been published from around 2005 onwards, the time the Millennium Ecosystem Assessment (MEA 2005) officially defined cultural ecosystem services and presented a framework to aid understanding of ecosystem functions and processes and the relationship to human benefits and well-being.

A systematic, quantitative literature review was conducted using the technique of Pickering and Byrne (2013). Between October 2014 and May 2015 the Web of Science (all databases) was searched for studies using combinations of keywords of urban green space and their use. Those for social attributes were cultural ecosystem services, outdoor recreation, visitor preferences, visitor perception(s), visitor behaviour and social values and those for physical attributes were green infrastructure, forest inventory, urban park characteristics, biodiversity, GPS, GIS, spatially explicit, spatial pattern, urban forest, urban green space, urban parks and mapping. Systematically, each social keyword was combined with each physical keyword, e.g. "cultural ecosystem services" AND "green infrastructure", "cultural ecosystem services" AND "forest inventory", and so on. The initial search yielded a total of 434 papers. These were screened according to the following criteria:

- Was the study conducted in Europe?
- Does the study deal with urban green infrastructure?
- Does the study assess both demand and supply factors?
- Are the physical factors spatially explicit? Is it a supply inventory (not just perceptions of participants)?
- Does the study link demand and supply factors?
- Is there a link to the use of green space and resulting benefits?

The study was included if all these questions could be answered with "yes".

Additional articles were identified from the bibliographies of those articles found through the database search and by looking for papers citing the articles in our sample. This resulted in 23 papers selected for the review.

As this review was conducted within the COST Action, additional relevant literature was sourced from the members of the whole COST Action, including publications not appearing in scientific databases. 129 studies were submitted from 13 countries. Using the same criteria, we included 17 in the review: 14 journal articles, 1 conference paper, 1 report and 1 book chapter. When added to the original 23 papers the final number of documents reviewed was 40.

To quantify the various factors studied, each paper was assessed for keywords and terms related to demand factors, quantitative (spatially explicit) supply characteristics and use and benefit variables, according to the Confluence Model. A bottom-up approach was used, relevant terms being added until no new ones emerged (Pickering and Byrne 2013). Each paper was then scored as a 1 or 0 (present or absent) for each identified term. Demand and supply factors significantly influencing use and benefit were also assessed. It is important to note that if a category was not present in a study this was either because it did not take these particular categories into account – even though there were some of these features – or there were simply none of these elements present in the corresponding green space.

Categories of demand factors were grouped into (1) "visitor's background" and (2) "visitor's perception/evaluation/assessment of features". Categories of supply factors were grouped into (1) physical (objective, quantifiable) characteristics or elements such as man-made infrastructure and biotic features, (2) the accessibility of the site, (3) the management and (4) factors such as tranquillity or aesthetics that more-or-less depend on individual perception. Categories in the first group were further clustered into aggregated sub-categories (Appendix 1) where they had similar content. Likewise, use and benefit variables were grouped into the seven subcategories of activities and visit frequency/visitor numbers, visitor preference, health, well-being, perceived restorativeness and happiness/mood.

Results

Overview of studies

Most of the 40 studies focused on urban forests or on urban (pocket) parks and a few on school yards or street trees. The bulk of the studies were in English, one paper in Spanish and one report in Dutch (Appendix 2). Papers were published in 19 different journals, Urban Forestry and Urban Greening and Landscape and Urban Planning being the most popular with nine and eight papers respectively. A cluster of health-related papers was published in various medical journals, e.g. Social Science & Medicine. The rest were distributed across forestry and landscape journals, general natural science, interdisciplinary, social science and economics orientated journals. Geographically, most studies were conducted in northern Europe, mainly in Scandinavia, the Netherlands, Switzerland and the UK. There was a clear increase in the rate of publication after 2012, with six to eight papers annually. This trend seems to be continuing, six papers having already been published between January and May 2015 when the literature search was conducted.

Data gathering methods

The 40 studies differed in their approaches for collecting social and physical data. Social data collection methods included on-site quantitative questionnaires (45%), off-site quantitative questionnaires (such as postal, online or telephone surveys) (35%), and visitor observations (17.5%). Two studies used stakeholder workshops or expert interviews. Several combined methods such as on-site and off-site questionnaire surveys. In some cases, secondary data such as population statistics were added. One study used visitor-employed photography (VEP). Sample sizes of on-site surveys or questionnaires ranged from 32 to several tens of thousands. Field experiments and VEP-approaches relied on low sample sizes, while mail/internet surveys yielded much higher ones. One on-site questionnaire of car-borne recreation at 2095 locations in Danish woodlands resulted in 28,947 completed questionnaires (Termansen et al. 2013).

Mapping of physical factors varied widely. Study area information was obtained by aerial or satellite photo interpretation, expert on-site field surveys or was derived from existing data such as forest maps or inventories. Some studies used standardized inventories or assessments such as Environmental Assessment of Public Recreation Spaces (EAPRS; Saelens et al. 2006), used to audit physical elements of parks (e.g. Peschardt et al. 2014); others developed their own mapping methods or classification systems to meet the study objectives (e.g. Voigt et al. 2014). Most physical data collection either mapped the components of the study areas and recorded them in GIS or used existing GIS-based land-use information (Table 1). Over half of the studies (52.5%) used expert field surveys to record the physical elements, particularly for urban parks. For larger areas, many studies (45% of the studies) used existing GIS data. Nine studies (22.5%) inventoried flora and fauna to link these to visitor preferences and their perceptions of biodiversity.

Table 1
Crosstable of studies (N = 40) with a combination of specific social and physical data collection approaches (Please note that several studies used several data collection approaches).

	Physical data collection approaches (supply)					Sum
Social data collection approaches (demand)	Available GIS data	Other available data on green areas	Visual recording of elements	Recording plant species	Photos	
Off-site questionnaire (Postal, online or telephone survey)	9	5	6	1	2	23
On-site quantitative questionnaire (visitors)	4	6	12	6	3	31
Stakeholder workshop or expert interviews	2	1	0	0	0	3
Visitor observations	4	3	4	2	2	15
Sum	19	15	22	9	7	

Linking demand and supply data

Over half the studies (57.5%) combined methods to link demand and supply data. Mostly, on-site questionnaires were combined with visual on-site recordings of elements while off-site questionnaire data were often combined with existing GIS data. The two studies using stakeholder workshops or expert interviews relied on available GIS data, while Colson et al. (2010) also used sets of descriptors covering both the physical characteristics of the woodland and the infrastructure present.

The final link between demand and supply was established either via statistical tools such as regression analysis or by overlapping different thematic maps. Predictive modelling approaches dominated, with different types of regression analysis (logistic, linear) and correlation being used in 55% of the studies. Researchers linking health and physical environment or physical activity and the physical environment almost always used regression analyses. Those focusing on social value mapping and physical data focused more on GIS and map interpretation (12.5%) or reported their results descriptively (5%). Three studies used logit models to analyse revealed or stated preferences combined with spatially explicit site evaluations.

Demand factors
Two-thirds of the studies collected typical socio-demographic data. Fifteen percent examined social or environmental values. The most common demand factors were related to visitor perception and evaluation of a site (Fig. 2). In 30% of the studies visitors were asked whether they liked or disliked the site or certain features and how they evaluated the aesthetic qualities. Perception of biodiversity was reported in 32.5% of the studies. Accessibility, comfort and infrastructure were present in 20% of the studies and naturalness/management in 22.5%. Spiritual, educational and research services were not examined at all, nor the contribution of green space to cultural heritage and sense of place.

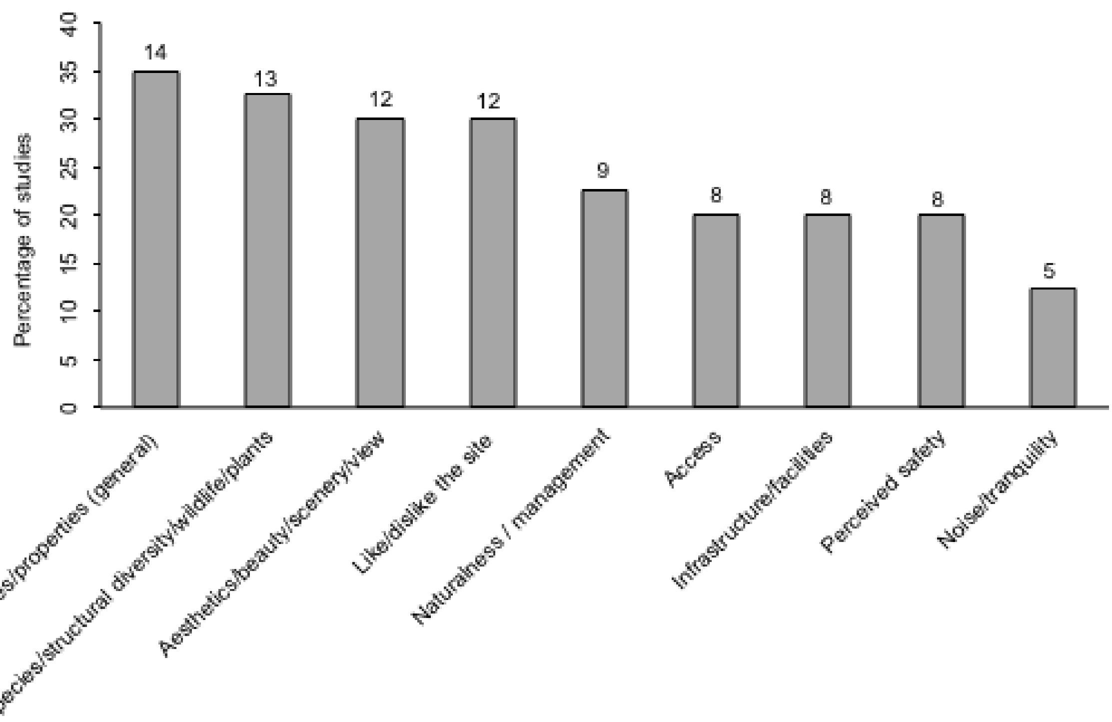

Fig. 2. Visitors' perception, evaluation or assessment of features of urban green spaces. Numbers on top of bars indicate number of studies.

Supply factors

Over half of the studies (62.5%) used data about the size or shape of the green space (Fig. 3) and 57.5% collected data on facilities for sport, play or relaxation, though only their presence or quantity were usually taken into account, not their respective qualities. Close to half of the studies (45%) included water or access to water (e.g. shorelines of rivers or lakes). To assess links with wellbeing benefits and visitor's spatial preferences or behaviour, 52.5% of the studies mapped habitat, structural or even species diversity. Low vegetation types (lawns, seedlings, flower beds, etc.) and tree cover or number of trees were assessed more often than eye-level vegetation such as bushes, hedges or shrubs. Rare categories were "geomorphological landforms" (25%) and "artistic features" (20%). The provision of shade as a key factor influencing use was directly covered in only two papers but indirectly in the category of tree cover or number of trees.

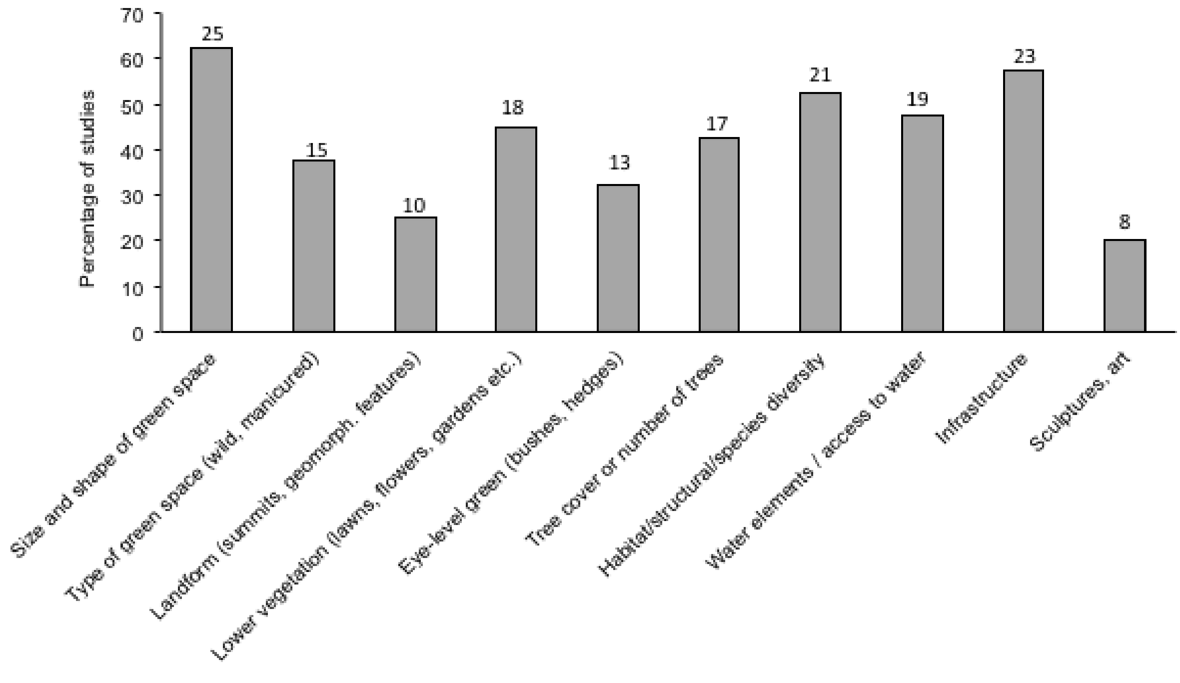

Fig. 3. Supply factors dealt with in the 40 studies. Numbers on top of bars indicate number of studies.

Accessibility is seen as a crucial indicator for the urban green space benefits. One third of the papers assessed the distance to green spaces and their accessibility in terms of entrances or reachability. The supply and distribution of green spaces in the city, district, or neighbourhood was addressed in 32.5% of the studies.

Concerning management and planning, 37.5% of the studies studied an urban green space's wild or manicured appearance. Most studies surveyed the current situation of one or several urban green spaces, only a few discussing the impacts of land use change, the increase of human pressure, the impact of forest management changes (e.g. by a scenario; Horne et al. 2005) or how small alterations in the physical character (such as thinning out of eye-level vegetation or the creation of paths and promenade) change the behavioural patterns in open space users (Unt and Bell 2014).

Some of the factors surveyed were based or depended on individual perceptions as well as on the visitor motivation. Aesthetic aspects, e.g. the general appearance of the space or of particular elements or views, were essential qualities examined in 42.5 % of the studies. A few measured perceptual factors such as (traffic) noise, tranquillity or sound in general (including bird song) using noise level meters (e.g. Caspersen and Olafsson 2010) or the perception of unwanted noise (e.g. Peschardt and Stigsdotter 2013). Some studies (17.5%) also dealt with litter pollution or properties that can lead to feeling unsafe (such as the absence of lighting or signs of vandalism).

Use and benefits
Use of green spaces - types of activities and frequency of use - was assessed in 35% of the studies. Benefits such as general health (30%), perceived restorativeness (20%), self-reported mood (10%) and well-being (15%) were most common, compared with socio-economic benefits (7.5%), fascination/being away (5%), creativity (2.5%) or concentration (7.5%). Only one study examined actual measured stress (cortisol concentration, blood-pressure, ECG).

Significant relationships between demand and supply factors and the dependent use and benefit variables
Only seven studies reported significant effects of demand factors. Van Herzele and de Vries (2012) found that perceived stress had a negative, while social cohesion had a positive effect on happiness. Being employed reduced the number of visits to close-to-home recreation areas in Neuvonen et al. (2007). In a Danish study, respondents were more likely to use their nearest urban green space if they had children under 6 years old, a dog, if they were over 70 years of age or if their health was not so good (Schipperijn et al. 2010). Similarly, self-reported health and education had a positive effect on physical activity in general and in the nearest green space, while age had a negative effect (Schipperijn et al. 2013). Physical activity in children was determined by the gender of the child, with boys being more active than girls (Andersen et al. 2015). Socio-demographics as well as social and environmental values had an influence on stakeholders' preferences concerning the management of an urban forest in Northern Sweden (Nordström et al. 2011). Perceived sensory dimensions affected perceived restorativeness in small public urban green spaces (Peschardt and Stigsdotter 2013).

Table 2 shows the supply factors found to be significantly associated with use and benefit variables. Habitat/structural or species diversity had an influence on health, wellbeing, restorativeness, visitor preference and visit frequency or visitor number in 45% of the studies. However, the direction of this influence is not consistent across the studies. While (bio-)diversity generally had a positive effect (Scopelliti et al. 2012, Carrus et al. 2015, Muratet et al. 2015), species richness had no effect or even a negative effect on well-being and visitors' evaluation of the site (Dallimer et al. 2012, Qiu et al. 2013). In urban parks, features such as dense vegetation or spaces enclosed by eye-level green were preferred for promoting the feeling of privacy and 'being away' (Nordh et al. 2009), but had negative influences on 'socialising' (Peschardt et al. 2014) or even provided an unsafe feeling (Unt and Bell 2014). In contrast, areas allowing a good overview on the park or to outside the park, provided an opportunity 'to see and to been seen' (Voigt et al. 2014). Infrastructure had an effect on visitor preference, activity and visitor number in 22.5% of the studies and recreation facilities were interpreted differently according to their 'site-appropriateness'. Nielsen et al. (2012) showed that a lot of people disliked constructed facilities in a forest despite their being intended to support recreational use. Visit frequency or visitor number were the dependent variables most often influenced by the measured physical factors (in 75% of the studies) followed by effects on wellbeing (37.5%), preferences and activities (32.5% each) and restorativeness (30%). Elements such as water presence, large green areas, short distances to the green space and moderate hills with viewpoints attracted visitors; however, this changed if the trails became steep (Neuvonen et al. 2007, Colson et al. 2010, Kienast et al. 2012, Termansen et al. 2013). The actual activities were largely determined by the infrastructure available (Schipperijn et al. 2013, Unt and Bell 2014, Andersen et al. 2015).

Table 2. Supply factors significantly influencing use and benefit variables in the 40 studies. Numbers indicate number of studies. (Please note that several studies used several variables)

Supply factors	**Use and benefit** Health	Well-being	Restorative-ness	Happiness / mood	Visitor preference	Activities	Visit frequency / visitor numbers
Size and shape of green space	-	1	1	1	-	1	3
Type of green space	-	-	1	1	-	-	1
Supply and distribution of green spaces	2	-	1	1	-	1	1
Landform	-	-	-	-	-	-	3
Water	-	1	1	-	1	1	3
Lower vegetation	1	1	1	-	-	2	1
Eye-level green	1	-	1	-	-	1	-
Tree cover / number of trees	1	1	1	-	-	1	1
Habitat / structural / species diversity	2	5	3	-	5	-	3
Sculptures / art	-	-	-	-	-	-	-
Tranquility	-	1	-	-	-	1	-
Aesthetics, view	-	1	1	1	2	1	3
Naturalness / management	-	1	1	1	1	-	4
Shade	-	1	-	-	-	-	-
Infrastructure	-	1	-	-	2	3	3
Access	-	1	-	-	1	1	4
Negative factors	-	-	-	-	1	-	-

Discussion

This study relied on a conceptual framework, the confluence model, to identify demand and supply variables influencing use and benefit variables. The study found a wide variety in methods used and demand and supply factors assessed in the literature reviewed. Several studies successfully linked demand and supply factors; however, many relationships were not significant and several potential demand and supply factors were not used or linked. Hence, it seems that the proposed confluence model linking biophysical green supply with social and individual demand in creating human benefits makes intuitive sense in current research, but that these supply-demand relationships are complex, context dependent, and far from fully researched. In the following we will discuss each part of the model based on our results, and also findings outside Europe.

Data gathering and linkage methods

The most common methods were quantitative off-site questionnaires combined with GIS or other data or on-site questionnaires combined with the visual recording of park elements. On-site questionnaires in combination with GIS were rare. There is potential to develop this combination, for example towards Public Participatory GIS (PPGIS), and to include landscape value mapping in visitor surveys (Beeco and Brown 2013). Similarly, recording plant species and/or wildlife together with social data collection was uncommon, perhaps because of the specialized knowledge required. This gap was also highlighted in another recent global review addressing the people-biodiversity interface where it was concluded that out of 200 publications almost no studies considered the cultural diversity of urban residents in assessments of biological diversity (i.e. 'biocultural diversity'; Botzat et al. 2016). The confluence model can be applied to spatially explicit photos, be it in the form of VEP as described earlier on (Qiu et al. 2013), via usage of geo-tagged social media data, e.g. photos on platforms such as panoramio (Casalegno et al. 2013) or in a retrospective analysis of historical photos (Szücs et al. 2015). Another future application of the confluence model would be the inclusion of functional traits on the supply side and linking them to CES (Goodness et al. 2016).

While CES currently rely more on qualitative assessment than does the assessment of other ES (Hernández-Morcillo et al. 2013, Plieninger et al. 2015), none of the spatially explicit studies reviewed here used only qualitative research. Research from the USA demonstrates that combining focus groups with participatory mapping yields spatially explicit findings (Lowery and Morse 2013). Combining quantitative and qualitative data provides deeper insights about socio-environmental systems (Bauer et al. 2004, Hunziker et al. 2008). It might be worth exploring the relationship of supply, demand, and benefit/use factors more deeply by adding qualitative methods.

Demand factors

Demand factors included socio-demographics, social and environmental values and visitors' perception of sites and features. All studies focused on recreational and aesthetic cultural ecosystem services but spiritual, inspirational, educational and research services, cultural heritage and sense of place (Altman and Low 1992) were absent. This was similar to what Milcu et al. (2013) found, although spiritual, inspirational and educational motives are important (Manfredo et al. 1996, Raadik et al. 2010). Some recreation studies do touch upon these themes although not in a spatially explicit way (e.g. Dwyer et al. 1991, O'Brien and Murray 2007, Plieninger et al. 2013, Plambech and Konijnendijk van den Bosch 2015). More attention could be given to linking green infrastructure and non-recreational CES. However, this would need ways to measure these human dimensions (Gobster and Westphal 2004) to link them with (quantitative) demand variables. Exploration by qualitative approaches might open the door for integration into the Confluence model presented in Fig. 1.

Supply factors

The most common supply factors are site size and shape as well as man-made infrastructure and natural elements or properties such as vegetation types or biotic diversity and water elements. There is less on subjective and perceptual factors and quality aspects. Visual aesthetics and noise pollution receive most attention but other senses have been ignored, even if urban nature appeals to all senses – smells, natural sounds and tactile experiences being reported as essential for nature experiences (Sotomayor et al. 2014). Nielsen et al. (2012) suggest that subtle, temporal and ephemeral aspects (such as weather conditions, seasonal changes) are essential to the on-site experience and ought to be considered. Few studies deal with the "supply factor" of wildlife and its attractiveness (Fuller et al. 2007, Dallimer et al. 2012, Voigt and Wurster 2015). This may be due to the more labour-intensive data collection necessary for such studies. Site cleanliness was also rarely considered (Verlič et al. 2015). Studies on urban parks usually regard maintenance and cleanliness as two of the most important aspects; poor maintenance (also a symbol for reduced safety) is seen as a property that reduces or prevents visits (e.g. Gobster and Westphal 2004, McCormack et al. 2010). In addition, there is little research on negative aspects preventing some people from using an urban green space or for not maximising their benefits. The lack of research on ecosystem disservices (ecosystem functions that have effects that are harmful to human well-being) has been criticised before and this is only a recent feature of studies (Lyytimäki and Sipilä 2009, von Döhren and Haase 2015). The inclusion of spatially explicit indicators of disservices as in Dobbs et al. (2014) can highlight areas of low ecosystem service provision and provide valuable information for city planning. For future use the confluence model could be extended to include disservices on the physical side and reasons for not using urban green spaces on the social side.

Use and benefits

Use of green spaces was associated with several benefits, especially perceived restorativeness, general health and wellbeing. However, most studies relied on self-reported measures, comparatively easily assessed using standardized questionnaires. Exceptions were Tyrväinen et al. (2014) who measured cortisol as an indicator for stress and de Vries et al. (2013) who did concentration tests with school children to measure the effects of green school grounds. Kabisch et al. (2015) also noted that as perceived stress is subjective, it could be valuable to include more objective measures in order to create a better picture of benefits. Further, it should be noted that ecosystems provide many other benefits and dimensions of human-wellbeing grounded in e.g. spiritual health, inspiration and identity (Russell et al. 2013), which have not been covered in the reviewed studies here.

Significant relationships between demand and supply factors and use and benefits
Analysis of relationships showed that both demand and supply factors influenced use and benefits in different, sometimes even contradictory, ways depending on the context, e.g. the presence of vegetation could promote the feeling of privacy but also lead to a perceived lack of safety.

Results indicate that the leg linking supply factors with benefits and uses of the Confluence Model (Fig. 1) has received more empirical evidence than the leg linking demand factors with benefits and uses. Socio-demographic parameters were recorded in two-thirds of the studies; however, only seven reported significant effects of demand factors such as socio-demographics, general health or perceived stress on use and benefit variables. There are two possible explanations for this. Either the effects of the supply factors override the effects of the demand factors or the role of the demand factors was not included in the studies because the focus was on the influence of the supply factors. Supply factors impacted most often on visit frequency and visitor numbers and also on activities. General health was the benefit assessed most often, though supply factors only rarely have an influence on health. Far greater effects were found on wellbeing and restorativeness. Kabisch et al. (2015) also found that while everyone agreed that urban green spaces are beneficial for the urban quality of life, the evidence on positive health effects was not clear and sometimes contradictory. Similarly, Hartig et al. (2014) concluded that while positive, short-term effects of contact with nature are reasonably well established, the effects found in population-level studies are often small compared to structural characteristics such as income, employment or education.

Conclusions and implications for future research
Several authors have stressed the importance of linking CES to spatially explicit ecological and physical structures to improve urban planning (Daniel et al. 2012, Hernández-Morcillo et al. 2013, Kabisch et al. 2015). We present and suggest the confluence model to guide this call for more research. In analysing the few studies that fulfil the requirements of the confluence model with spatially explicit outputs we found few significant variables and contradictory results. In general, social and environmental values and visitor perception or evaluation of a site with its features and infrastructure are linked to size and shape of green space, recreational infrastructure, diversity measures, measures of amount of vegetation and accessibility. In some cases, employment, age, gender and social and environmental values influenced the use of green space and physical activity, while species or structural diversity more often had an influence on health, wellbeing, restorativeness

and visit frequency or visitor numbers. Infrastructure mainly impacted on visitor activities and visitor numbers. So there seem to be relationships between landscape, forest or park characteristics on the one hand and demand factors on the other but it is difficult to pin them down. Maybe improving and harmonizing of methodologies and moving towards intervention studies (experiments manipulating the physical characteristics and subsequent evaluations of changes in visitors' behaviour, perception, etc.) as in Unt and Bell (2014) could clarify some of these relationships.

It should be noted that this review only deals with European studies. However, multiple recent global reviews have reported that Europe (together with North America and Northeast Asia) is a forerunner in research focused on linkages between people and green spaces (Kabisch et al. 2015, Botzat et al. 2016). Further, most studies in our sample were even conducted in northern Europe. As findings are not always generalizable due to differences in socio-cultural background and behaviour as well as ecological conditions and infrastructure, there is a need to conduct studies more widely. Studies comparing different climatic zones and different culture-based nature perceptions (Roy et al. 2012, Kabisch et al. 2015) are also rare. Notable exceptions such as Lafortezza et al. (2009) comparing park visitors in Italy and the UK, and Arnberger et al. (2010) comparing park visitors in Austria and Japan, could easily be supplemented with data on physical characteristics to broaden the picture. Something similar applies to the numerous studies being conducted on the use of parks and forests by different ethnic groups (for a review see Kloek et al. (2013)), different age groups (Bell et al. 2003, Jorgensen and Anthopoulou 2007), different activity groups (e.g. Arnberger 2006), etc. Linking data from such studies to spatially explicit physical characteristics could provide additional value for management and planning.

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Appendix

Appendix 1

Aggregation of supply factors studied in 40 studies

Original factors	Aggregated factors
Size of green space Shape of green space	Size and shape of green space
Type of green space (wild, manicured)	Type of green space
General infrastructure (e.g. toilets, lighting, parking) Hardscape Infrastructure for sports and play Hiking / biking trails / walks, paths Infrastructure for relaxation (benches, picnic places)	Infrastructure
Summits, relief (hill, knoll, slopes) Geomorphological features, rocks Geological, natural hotspots (e.g for education, tourism)	Landform (summits, geomorphological features)
Water elements, access to water River Coastline	Water elements, access to water
Flower tubs / beds / flowering plants Gardens (in parks) Green ground cover Growth, young trees, seedlings, regeneration Lawns, meadows, grass Lower vegetation	Lower vegetation (lawns, flowers, etc.)
Area of eye-level green	Eye-level green (bushes, hedges)
Area of tree canopy (tree cover or number) Street trees	Tree cover / number of trees
Wildlife, particular animal species Dominant tree species (conifers, broadleaves) Fallen wood and plant debris	Habitat / structural / species diversity
Sculptures, art / heritage	Sculptures, art
Perceptual factors	
Silent area General noise, tranquility Traffic noise	(Traffic) noise, tranquility
Measured overall aesthetics / scenery View Visibility (distance / visual penetration)	Overall aesthetics, view
Naturalness	Naturalness

Shade	Shade
Negative factors, risks (neg. atmosphere, flooding, etc.)	Disservices, negative factors

Appendix 2

Overview of the studies assessed in this review sorted according to date

Authors	Title	Published in	Country
Wendel-Vos, W.G.C., Schuit, A.J., de Niet, R., Boshuizen, H.C., Saris, W.H.M., Kromhout, D., 2004	Factors of the physical environment associated with walking and bicycling	Medicine & Science in Sports & Excercice 36, 725-730.	Nether-lands
Germann-Chiari, C., Seeland, K., 2004	Are urban green spaces optimally distributed to act as places for social integration? Results of a geographical information system (GIS) approach for urban forestry research	Forest Policy and Economics 6, 3-13.	Switzer-land
Horne, P., Boxall, P.C., Adamowicz, W.L., 2005	Multiple-use management of forest recreation sites: a spatially explicit choice experiment	Forest Ecology and Management 207, 189-199.	Finland
Hillsdon, M., Panter, J., Foster, C., Jones, A., 2006	The relationship between access and.quality of urban green space with population physical activity	Publi Public Health 120, 1127-1132.	UK
Neuvonen, M., Sievänen, T., Tönnes, S., Koskela, T., 2007	Access to green areas and the frequency of visits - A case study in Helsinki	Urban Forestry & Urban Greening 6, 235-247.	Finnland
Tyrväinen, L., Mäkinen, K., Schipperijn, J., 2007	Tools for mapping social values of urban woodlands and other green areas	Landscape and Urban Planning 79, 5-19.	Finland
Fuller, R.A., Irvine, K.N., Devine-Wright, P., Warren, P.H., Gaston, K.J., 2007	Psychological benefits of greenspace increase with biodiversity	Biol Lett 3, 390-394.	UK
Lange, E., Hehl-Lange, S., Brewer, M.J., 2008	Scenario-visualization for the assessment of perceived green space qualities at the urban–rural fringe	J Environ Manage 89, 245-256.	Switzer-land
Schipperijn, J., Stigsdotter, U.K., Randrup, T.B., Troelsen, J., 2010	Influences on the use of urban green space – A case study in Odense, Denmark	Urban Forestry & Urban Greening 9, 25-32.	Denmark
Nordh, H., Hartig, T., Hagerhall, C.M., Fry, G., 2009	Components of small urban parks that predict the possibility for restoration	Urban Forestry & Urban Greening 8, 225-235.	Sweden
Colson, V., Garcia, S., Rondeux, J., Lejeune, P., 2010	Map and determinants of woodlands visiting in Wallonia	Urban Forestry & Urban Greening 9, 83-91.	Belgium
Caspersen, O.H., Olafsson, A.S., 2010	Recreational mapping and planning for enlargement of the green structure in greater Copenhagen	Urban Forestry & Urban Greening 9, 101-112.	Denmark

Vega-Garcia, C., Burriel, M., Alcazar, J., 2011	Valoración social de las propiedades estéticas de los hayedos	Forest Systems 20, 195-208.	Spain
Nordström, E.-M., Eriksson, L.O., Öhman, K., 2011	Multiple criteria decision analysis with consideration to place-specific values in participatory forest planning	Silva Fennica 45, 253-265	Sweden
Van Herzele, A., de Vries, S., 2012	Linking green space to health: a comparative study of two urban neighbour-hoods in Ghent, Belgium	Population & Environment 34, 171-193	Belgium
Kienast, F., Degenhardt, B., Weilenmann, B., Wäger, Y., Buchecker, M., 2012	GIS-assisted mapping of landscape suitability for nearby recreation	Landscape and Urban Planning 105, 385-399.	Switzer-land
Scopelliti, M., Carrus, G., Cini, F., Mastandrea, S., Ferrini, F., Lafortezza, R., Agrimi, M., Salbitano, F., Sanesi, G., Semenzato, P., 2012	Biodiversity, perceived restorativeness and benefits of nature: a study on the psychological processes and outcomes of on-site experiences in urban and peri-urban green areas in Italy	Kabisch, S., Kunath, A., Schweizer-Ries, P., Steinführer, A. (Eds.), Vulnerability, Risks, and Complexity: Impacts of Global Change on Human Habitats. Hogrefe Publishing, pp. 255-269.	Italy
Dallimer, M., Irvine, K.N., Skinner, A.M.J., Davies, Z.G., Rouquette, J.R., Maltby, L.L., Warren, P.H., Armsworth, P.R., Gaston, K.J., 2012	Biodiversity and the Feel-Good Factor: Understanding Associations between Self-Reported Human Well-being and Species Richness	BioScience 62, 47-55.	UK
Nielsen, A.B., Heyman, E., Richnau, G., 2012	Liked, disliked and unseen forest attributes: Relation to modes of viewing and cognitive constructs	J Environ Manage 113, 456-466.	Sweden
van Dillen, S.M., de Vries, S., Groenewegen, P.P., Spreeuwenberg, P., 2012	Greenspace in urban neighbourhoods and residents' health: adding quality to quantitiy	J Epidemiol Community Health 66, e8.	Nether-lands
Arnberger, A., Eder, R., Taczanowska, K., Deussner, R., Stanzer, G., Hein, T., Preiner, S., Kempter, I., Nopp-Mayr, U., Reiter, K., Wagner, I., Jochem, R., 2013	Urban sprawl and protected areas: How effective are buffer zones in reducing recreation impacts on an urban national park?	5th Symposium for Research in Protected Areas, Mittersill, Austria, pp. 21-26.	Austria

Peschardt, K.K., Stigsdotter, U.K., 2013	Associations between park characteristics and perceived restorativeness of small public urban green spaces	Landscape and Urban Planning 112, 26-39.	Denmark
de Vries, S., Langers, F., Donders, J.L.M., Willeboer, M., van den Berg, A.E., 2013a	Meer groen op het schoolplein: een interventiestudie; de effecten van het groen herinrichten van schoolpleinen op de ontwikkeling, het welzijn en de natuurhouding van het kind	Alterra-rapport 2474. University of Wageningen, Wageningen, The Netherlands, p. 188.	Nether-lands
de Vries, S., van Dillen, S.M., Groenewegen, P.P., Spreeuwenberg, P., 2013b	Streetscape greenery and health: stress, social cohesion and physical activity as possible mediators	Soc Sci Med 94, 26-33.	Nether-lands
Termansen, M., McClean, C.J., Jensen, F.S., 2013	Modelling and mapping spatial heterogeneity in forest recreation services	Ecological Economics 92, 48-57.	Denmark
Abildtrup, J., Garcia, S., Olsen, S.B., Stenger, A., 2013	Spatial preference heterogeneity in forest recreation	Ecological Economics 92, 67-77	France
Schipperijn, J., Bentsen, P., Troelsen, J., Toftager, M., Stigsdotter, U.K., 2013	Associations between physical activity and characteristics of urban green space	Urban Forestry & Urban Greening 12, 109-116.	Denmark
Qiu, L., Lindberg, S., Nielsen, A.B., 2013	Is biodiversity attractive? - On-site perception of recreational and biodiversity values in urban green space	Landscape and Urban Planning 119, 136-146.	Sweden
Tyrväinen, L., Ojala, A., Korpela, K., Lanki, T., Tsunetsugu, Y., Kagawa, T., 2014	The influence of urban green environments on stress relief measures: A field experiment	Journal of Environmental Psychology 38, 1-9.	Finnland
Peschardt, K.K., Stigsdotter, U.K., Schipperrijn, J., 2014	Identifying features of pocket parks that may be related to health promoting use	Landscape Research, 1-16.	Denmark
Voigt, A., Kabisch, N., Wurster, D., Haase, D., Breuste, J., 2014	Structural diversity: A multi-dimensional approach to assess recreational services in urban parks	Ambio 43, 480-491.	Germany / Austria
Adinolfi, C., Suárez-Cáceres, G.P., Cariñanos, P., 2014	Relation between visitor's behaviour and characteristics of green spaces in the city of Granada, south-eastern Spain	Urban Forestry & Urban Greening 13, 534-542.	Spain

Casado-Arzuaga, I., Onaindia, M., Madariaga, I., Verburg, P.H., 2014	Mapping recreation and aesthetic value of ecosystems in the Bilbao Metropolitan Greenbelt (northern Spain) to support landscape planning	Landscape Ecology 29, 1393-1405.	Spain
Unt, A.-L., Bell, S., 2014	The impact of small-scale design interventions on the behaviour patterns of the users of an urban wasteland	Urban Forestry & Urban Greening 13, 121-135.	Estonia
Voigt, A., Wurster, D., 2015	Does diversity matter? The experience of urban nature's diversity. Case study and cultural concept	Ecosystem Services 12, 200-208.	Austria
Verlič, A., Arnberger, A., Japelj, A., Simončič, P., Pirnat, J., 2015	Perceptions of recreational trail impacts on an urban forest walk: A controlled field experiment	Urban Forestry & Urban Greening 14, 89-98.	Slovenia
Carrus et al. (2015)	Go greener, feel better? The positive effects of biodiversity on the well-being of individuals visiting urban and peri-urban green areas.	Landscape and Urban Planning	Italy
Taylor, M.S., Wheeler, B.W., White, M.P., Economou, T., Osborne, N.J., 2015	Research note: Urban street tree density and antidepressant prescription rates - A cross-sectional study in London, UK.	Landscape and Urban Planning 136, 174-179.	UK
Muratet, A., Pellegrini, P., Dufour, A.-B., Arrif, T., Chiron, F., 2015	Perception and knowledge of plant diversity among urban park users	Landscape and Urban Planning 137, 95-106.	France
Andersen, H.B., Klinker, C.D., Toftager, M., Pawlowski, C.S., Schipperijn, J., 2015	Objectively measured differences in physical activity in five types of schoolyard area	Landscape and Urban Planning 134, 83-92.	Denmark

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